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Research Article

Utilization of Mixed Maggot Flour (*Hermetia illucens*) and Taro Leaves (*Colocasia esculenta*) for the Growth of Nile Tilapia (*Oreochromis niloticus*)

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Abstract

Tilapia (*Oreochromis niloticus*) is a popular freshwater fish with promising development prospects due to its clean white flesh, high nutritional content, and affordability. However, feed costs in tilapia farming pose challenges, particularly with rising prices of fish meal, the primary protein source. Maggot (*Hermetia illucens*) and taro leaves (*Colocasia esculenta*) offer an alternative protein source for tilapia feed due to their high protein content. This study, conducted over 30 days in Marga Agung Village, South Lampung, tested the effects of different feed mixtures using a completely randomized design (RAL) with 4 treatments and 3 repetitions. The study involved 120 tilapia, evaluating parameters such as weight gain, specific growth rate (SGR), absolute length, feed conversion ratio (FCR), temperature, and pond clarity. Data analysis via ANOVA and Duncan's test showed the highest results in the control group (P0), with an average weight of 8.43g, an SGR of 28%, and an FCR of 1.42. Treatment P2 (50% maggot and 50% taro leaves) produced comparable results, with an average weight of 8.09g, an SGR of 27%, and an FCR of 1.44. Environmental conditions remained stable across treatments, with pH and water clarity showing minimal variation. These results suggest that a 50% maggot and 50% taro leaf mixture could be a viable alternative to fish meal for tilapia feed without significant differences in growth performance compared to the control.

Keywords: Flour; Growth; Maggot; Taro Leaves; Tilapia.

Publisher's Note:

INTRODUCTION

Indonesia is a maritime country with the largest potential in the field of fishery products. Fishery production in Indonesia includes the cultivation of marine, brackish water, and freshwater fish. Freshwater fish farming contributes up to 1.1 million tons, with the rest from brackish water and marine aquaculture [1], [2], [3]. One important freshwater fish species is Nile tilapia, which plays a significant role in global aquaculture production [4], [5], [6]. According to the FAO (Food and Agriculture Organization), there was still a global shortage of 2 million tons of fish annually by 2010, and a similar trend is seen in the domestic market [7], [8], [9].

Nile tilapia (*Oreochromis niloticus*) is a crucial freshwater fish commodity in Indonesia, with great potential to support national food security. This fish species is known for its fast growth rate and high productivity compared to other freshwater species. Additionally, tilapia is favored for its distinctive taste, clean and boneless flesh, and high nutritional value. The nutritional content of tilapia includes 43.76% protein, 7.01% fat, and 6.80% ash per 100 grams of fish weight [10], [11], [12]. With low cholesterol levels, tilapia is often used as an affordable and easily accessible source of animal protein for the public, fulfilling basic human needs such as food and nutrition [13].

Developing tilapia farming requires improvements in various aspects, including feed technology [14], [15]. One strategy is the fortification of feed with other ingredients to reduce production costs. Feed is a crucial aspect of fish farming, serving as the main energy source for growth. High-quality feed must meet the physiological needs of the fish species and fulfill their nutritional requirements [16], [17]. Feed must be provided in the right quality, quantity, timing, and nutrient balance, including proteins, fats, carbohydrates, minerals, and vitamins [18]. Feed with a high protein content is considered to have better quality and can optimize fish growth [19].

The high price of commercial feed, mainly due to the cost of fish meal, has led to increased production costs, reducing farmers' income. Feed accounts for about 60-70% of total production costs. Therefore, more affordable and accessible protein alternatives, such as maggot and taro leaves, are needed [20]. Black soldier fly larvae (BSF) maggot has long been used as a source of animal feed protein due to its ability to convert food waste into high-quality protein [21], [22]. he advantage of maggot as a protein source is its ability to process organic materials, requiring minimal land and water, while producing natural enzymes that improve fish digestibility. Maggot from the black soldier fly (*Hermetia illucens*) is rich in nutrients and offers a more affordable solution for fish feed, without harming water quality and improving fish resilience [23], [24].

Taro leaves (*Colocasia esculenta*) are a valuable food source, rich in carbohydrates, proteins, fats, minerals, and vitamins, making them suitable for fish feed. Taro leaves are easy to obtain, as the plant adapts well to both dry and wet environments such as swamps [25]. Taro leaves contain high protein levels and are easily accessible, making them an excellent source of plant-based protein for fish feed. The combination of maggot and taro leaves offers a balanced protein source for Nile tilapia (*Oreochromis niloticus*), with one of the key benefits being their high protein content.

Taro leaves are rich in nutrients, including 27.80% protein and 3,821 kcal/g of gross energy, along with essential amino acids such as tryptophan and lysine. Since plant-based proteins are not as complete as animal proteins, animal protein sources must be added to fulfill essential amino acid requirements. Feed that contains two or more protein sources has been proven to support better fish growth [25], [26], [27].

Maggot is a high-quality animal protein source, containing 41-42% crude protein, 31-35% ether extract, 14-15% ash, 4.8-5.1% calcium, and 0.6-0.63% phosphorus in its dry form [28] It also contains a complete amino acid profile, including serine, glycine, histidine, arginine, threonine, alanine, proline, tyrosine, valine, cystine, isoleucine, leucine, lysine, taurine, cysteine, NH_3, and ornithine [29], [30], [31]. Protein is essential for growth, tissue repair, and energy in fish. Feed must provide adequate nutrients, such as proteins, fats, vitamins, carbohydrates, and minerals. Maggot and taro leaves are economical and easy-to-cultivate feed ingredients [24], [32].

Budi Prasetyo's study (2021) concluded that using fresh maggot (*Hermetia illucens*) as the sole protein source for catfish feed is ineffective, with the best results achieved by combining 50% maggot and 50% fish meal. Maggot is more effective when combined with other feed ingredients. The research gap here is to explore the combination of maggot with plant-based protein sources, such as taro leaves (*Colocasia esculenta*), to provide more balanced nutrition and improve fish growth. The novelty of this study is to develop a more economical and effective alternative feed formulation for Nile tilapia (*Oreochromis niloticus*) [33].

The objective of this research is to evaluate the impact of using a mixture of maggot flour (*Hermetia illucens*) and taro leaves (*Colocasia esculenta*) on the growth of Nile tilapia (*Oreochromis niloticus*). This study also aims to determine the most effective feed formulation to optimize tilapia growth. Thus, this research is expected to provide a more economical yet high-quality feed alternative for fish farmers, reducing dependency on expensive commercial feeds.

METHODS

This research was conducted from May 14 to June 12, 2023, in Marga Agung Village, Jati Agung District, South Lampung. The Nile tilapia (*Oreochromis niloticus*) fingerlings used in the study were obtained from a local fish breeder in Karang Anyar Village, Jati Agung District, South Lampung. Water quality measurements were carried out during the research period at the same location. The approach used in this study is experimental, employing a quantitative research design.

Research Design

The experimental design used in this study was a Completely Randomized Design (CRD), consisting of 4 treatments with 3 replications. The feed formulations used are as follows:

Table 1. Feed Formulation

Ingredients (g)	P0 (Control)	P1	P2	P3
Commercial feed	1000	-	-	-
Taro leaf flour	-	150	300	450
Maggot flour	-	450	300	150
Fine bran	-	300	300	300
Corn flour	-	50	50	50
Tapioca flour	-	20	20	20
Premix	-	20	20	20
Fish oil	-	10	10	10
Total	1000	1000	1000	1000

Table 1 shows the different feed formulations used in the study. The control group (P0) received 100% commercial feed, while the experimental groups (P1, P2, P3) received varying proportions of taro leaf flour and maggot flour. P1 was formulated with 75% maggot flour and 25% taro leaf flour, P2 with a 50/50 ratio of maggot and taro leaf flour, and P3 with 25% maggot flour and 75% taro leaf flour. All feed mixtures also included additional ingredients such as fine bran, corn flour, tapioca flour, premix, and fish oil.

Population, Sample, and Data Collection

The population in this study consists of Nile tilapia (Oreochromis niloticus) fingerlings sourced from a breeder in Karang Anyar Village. A total of 120 Nile tilapia fingerlings were used, distributed across 4 tanks, with 30 fish per tank. Five fish were randomly sampled from each tank using a sieve, with 3 replications. Observations were conducted on various growth parameters. Data collection techniques**,** the following growth parameters were measured:

1. **Absolute Weight Growth (W):**
   Absolute weight growth was calculated using the formula:
   $$\boldsymbol{W} = \boldsymbol{W_t} - \boldsymbol{W_o}$$
   Where W_t is the final fish weight and $\boldsymbol{W_o}$ is the initial fish weight.

2. **Specific Growth Rate (SGR):**
   The SGR was calculated using the formula:
   $$SGR = \frac{\boldsymbol{W_t}}{\boldsymbol{W_o}} \times 100\%$$
   Where *t* is the research duration.

3. **Absolute Length Growth:**
   Absolute length growth was measured using the formula:
   $$\Delta w = \boldsymbol{W_t} - \boldsymbol{W_i}$$
   Where $\boldsymbol{W_t}$ is the final length and $\boldsymbol{W_i}$ is the initial length.

4. **Feed Conversion Ratio (FCR):**
   FCR was calculated using the formula:

$$FCR = \frac{\boldsymbol{F}}{\boldsymbol{W}_t - \boldsymbol{W}_o}$$

   Where ***F*** is the total feed provided.

Environmental Parameters

The environmental parameters measured in this study included water pH and clarity, both of which are crucial for maintaining optimal growth conditions for Nile tilapia. The pH of the water was monitored using a digital pH tester. This device was immersed in the water, and readings were taken after 10-15 seconds to ensure accuracy. Maintaining a stable pH level is important as fluctuations can affect fish metabolism and overall health.

Water clarity was measured using a Secchi Disk, a tool commonly used to assess water transparency. The disk, marked with alternating black and white segments, was slowly lowered into the water until the segments were no longer visible. At this point, the depth was recorded. This method provided a reliable measure of water clarity, which can impact light penetration and the availability of nutrients for aquatic life. Regular monitoring of these parameters helped ensure that the water conditions remained suitable for the fish throughout the study.

Procedure

Preliminary research was conducted to identify the needs in the Arabic teaching and learning process. Based on

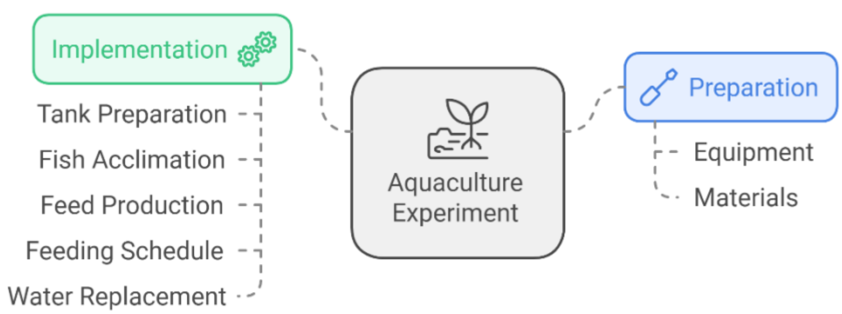

Figure 1. Procedure

The research procedure began with the preparation of tools and materials, including tanks, digital scales, pH testers, Secchi disks, pellet production equipment, and other necessary items such as fish, maggot flour, taro leaf flour, corn flour, tapioca flour, fine bran, premix, and fish oil. Four experimental tanks were set up, each with different feed treatments. The tanks, made of tarpaulin with dimensions of 50x50x80 cm, were filled with water and allowed to settle for 48 hours to stabilize water quality before introducing the fish.

The next step was the production of feed. This involved mixing maggot flour, taro leaf flour, corn flour, tapioca flour, fine bran, premix, and fish oil in predetermined proportions until

the mixture became homogeneous. The mixture was then processed into pellets using a manual meat grinder and sun-dried until fully dried.

Before the fish were introduced into the tanks, an acclimatization process was carried out to help the fish adjust to the new environment. This involved gradually introducing the fish to the tank water to reduce stress from changes in temperature, pH, and oxygen levels. Each tank was stocked with 30 Nile tilapia fingerlings, each weighing approximately 5 grams and measuring about 6 cm in length.

The maintenance phase lasted for 30 days, during which the fish were fed twice daily—once at 8:00 a.m. and again at 3:00 p.m. The amount of feed provided was 5% of the total fish biomass. Every 3 days, 50% of the water in each tank was replaced with fresh water to maintain water quality. Water clarity and pH levels were measured weekly, while the growth of fish (in terms of weight and length) was recorded every 10 days. This process was monitored closely to ensure proper feeding and water quality throughout the experiment, with regular observations made to assess the growth and overall health of the fish.

Data Prerequisite and Hypothesis Testing

Data prerequisite testing was conducted to ensure the validity of the statistical analysis. A normality test was performed to determine whether the data followed a normal distribution, which is essential for further statistical analysis. The data were considered normally distributed if the significance value was greater than 0.05. Additionally, a homogeneity test was performed to verify whether the variance across the data groups was consistent. The data were deemed homogeneous if the significance value exceeded 0.05.

For hypothesis testing, an Analysis of Variance (ANOVA) was used to evaluate whether there were significant differences between the treatments. The parameters analyzed included absolute weight growth, specific growth rate (SGR), absolute length growth, and feed conversion ratio (FCR). To further identify significant differences between treatments, Duncan's test was applied at a significance level of 0.05. The statistical analyses were performed using SPSS software to ensure accuracy and reliability of the results.

RESULT AND DISCUSSIONS

Data Description

The results of this study on the utilization of maggot flour and taro leaf flour for the growth of Nile tilapia (*Oreochromis niloticus*) were obtained over a 30-day period, using four treatment groups with three replications each. The key growth parameters measured include absolute weight gain, specific growth rate (SGR), absolute length growth, and feed conversion ratio (FCR). Environmental factors, such as pH and water clarity, were also measured to monitor the tank conditions. The results of these observations are summarized in Table 1, which presents the average values for each parameter across the different treatment groups.

Table 2. Average Research Results

Treatment	Absolute Weight (g)	SGR (%)	Absolute Length (cm)	FCR
P0 (Control)	8.43	28%	3.14	1.42
P1 (75% Maggot, 25% Taro Leaf)	4.72	16%	2.38	2.12
P2 (50% Maggot, 50% Taro Leaf)	8.09	27%	3.09	1.44
P3 (25% Maggot, 75% Taro Leaf)	4.27	14%	1.69	2.37

Table 1 shows the average research results for each treatment group over the 30-day study period. The table summarizes key growth parameters, including absolute weight gain, specific growth rate (SGR), absolute length growth, and feed conversion ratio (FCR) for Nile tilapia (*Oreochromis niloticus*). The control group (P0), which received 100% commercial feed, demonstrated the highest values in weight gain, SGR, and length growth, followed closely by P2, which used a 50:50 combination of maggot and taro leaf flour. Treatments P1 (75% maggot) and P3 (75% taro leaf) showed significantly lower growth and higher FCR values, indicating less efficient feed conversion compared to P0 and P2.

Statistical Analysis

1. **Prequisite Test (Normality and Homogeneity)**
   Normality and homogeneity tests were conducted using SPSS 22. All sample data across the parameters were found to have significance values greater than 0.05, indicating that the data were normally distributed and homogeneous. This confirmed that the data met the assumptions required for Analysis of Variance (ANOVA) testing.
2. **Hypothesis Testing (One-Way ANOVA)**
   A one-way ANOVA was performed to determine whether there were significant differences in the growth and feed efficiency of Nile tilapia between the different treatment groups. The results showed that the treatment had a significant effect on fish growth, with a p-value of less than 0.05 for all parameters. Duncan's post hoc test was used to further analyze the differences between specific treatments.

a. Absolute Weight Growth

Table 3. Absolute Weight Growth

Perlakuan	Rerata ± SD
P0	8,43 ± 0,40^{b}
P1	4,72 ± 0,27^{a}
P2	8,09± 0,37^{b}
P3	4,27 ± 0,25^{a}

Duncan's test indicated that P0 (control) and P2 (50% maggot, 50% taro leaf) had the highest absolute weight gains, with no significant difference between them. These groups both significantly outperformed P1 (75% maggot, 25% taro leaf) and P3 (25%

maggot, 75% taro leaf), indicating that a balanced combination of maggot and taro leaf produced better growth outcomes. The highest absolute weight was recorded in P0 (8.43 g), closely followed by P2 (8.09 g), while P1 (4.72 g) and P3 (4.27 g) demonstrated significantly lower growth rates. This suggests that the presence of both animal and plant protein sources is important for optimal fish growth.

b. Specific Growth Rate (SGR)

Table 4. Specific Growth Rate

Perlakuan	Rerata ± SD
P0	8,43 ± 0,40^{b}
P1	4,72 ± 0,27^{a}
P2	8,09± 0,37^{b}
P3	4,27 ± 0,25^{a}

The specific growth rate (SGR) also reflected a similar trend, with P0 (28%) and P2 (27%) showing the highest rates of growth. These two groups were statistically similar, while P1 (16%) and P3 (14%) had significantly lower SGR values. The lower SGRs in P1 and P3 could be attributed to the unbalanced nutrient profile provided by either too much maggot or too much taro leaf in the feed. The results emphasize that a 50:50 ratio of maggot and taro leaf flour (P2) is nearly as effective as commercial feed in promoting rapid fish growth.

c. Absolute Length Growth

Table 5. Absolute Length Growth

Perlakuan	Rerata ± SD
P0	8,43 ± 0,40^{b}
P1	4,72 ± 0,27^{a}
P2	8,09± 0,37^{b}
P3	4,27 ± 0,25^{a}

In terms of absolute length growth, P0 (3.14 cm) and P2 (3.09 cm) again outperformed P1 (2.38 cm) and P3 (1.69 cm), confirming the effectiveness of the balanced maggot and taro leaf combination. This result is consistent with previous studies suggesting that diets combining both animal and plant protein sources can lead to better growth performance compared to diets dominated by a single protein type.

d. Feed Conversion Ratio (FCR)

Table 6. Feed Conversion Ratio

Perlakuan	Rerata ± SD
P0	8,43 ± 0,40^{b}
P1	4,72 ± 0,27^{a}
P2	8,09± 0,37^{b}
P3	4,27 ± 0,25^{a}

The feed conversion ratio (FCR) was lowest in P0 (1.42) and P2 (1.44), indicating that these groups utilized feed more efficiently than P1 (2.12) and P3 (2.37). An FCR value below 1.5 is considered optimal for aquaculture, meaning that P2 achieved nearly the same feed efficiency as commercial feed (P0). In contrast, the higher FCR values in P1 and P3 suggest that the feed mixtures in these treatments were less efficient in promoting growth, likely due to an imbalance in nutrient content.

Environmental Parameters

The pH levels in the tanks remained relatively stable throughout the study, ranging from 7.4 to 7.5, which falls within the optimal range for Nile tilapia growth, according to the Indonesian National Standard (SNI) of 6.5 to 8.5. No significant variations in pH were observed that could have negatively impacted fish growth. Additionally, water clarity was measured using a Secchi disk, with values ranging from 39.2 cm to 48.7 cm. The highest clarity was recorded in the control group (P0) at 48.7 cm, followed closely by P2 at 48.4 cm. The lowest clarity was observed in P3 at 39.2 cm. These results suggest that higher maggot content in the feed, particularly in P1 and P3, may have contributed to reduced water clarity, potentially influencing fish behavior and feeding efficiency.

Discussion

This study confirms the potential of using maggot flour and taro leaf flour as alternative feed ingredients for Nile tilapia. The results show that the combination of 50% maggot and 50% taro leaf (P2) provided comparable growth performance to 100% commercial feed (P0), making it a viable and cost-effective alternative. This is particularly important in light of the increasing costs of fishmeal, which constitutes the bulk of commercial feed formulations.

The superior performance of P2 in terms of absolute weight growth, SGR, and FCR can be attributed to the balanced nutrient composition offered by the combination of animal protein (maggot flour) and plant protein (taro leaf flour). Previous studies have shown that diets containing a combination of protein sources tend to promote better growth than those relying on a single source, as they provide a more complete amino acid profile. The inclusion of both animal and plant proteins in P2 likely optimized nutrient absorption and utilization, leading to more efficient growth.

On the other hand, the lower growth rates and higher FCRs observed in P1 and P3 suggest that an imbalance in the proportion of maggot and taro leaf can negatively affect fish performance. Maggot flour, while rich in protein, contains chitin, which can be difficult for fish to digest in large quantities. This may explain the poorer performance in P1 (75% maggot) and P3 (25% maggot, 75% taro leaf), where the imbalance in nutrient content likely limited growth.

The environmental parameters, particularly pH and water clarity, were maintained within acceptable ranges throughout the study, ensuring that the differences in growth were primarily due to the feed treatments rather than external factors. However, the slightly lower water clarity in P1 and P3 suggests that higher maggot content may lead to reduced water quality, potentially impacting fish feeding behavior and growth.

CONCLUSION

The results of this study demonstrate that the combination of maggot flour (*Hermetia illucens*) and taro leaf flour (*Colocasia esculenta*) has a significant effect on the growth parameters of Nile tilapia (*Oreochromis niloticus*), including absolute weight gain, specific growth rate (SGR), absolute length growth, and feed conversion ratio (FCR). The 50:50 combination of maggot and taro leaf flour provides a balanced nutrient profile, supporting effective growth and feed efficiency comparable to commercial feeds. However, despite its potential as a cost-effective and sustainable alternative, the formulation was not entirely optimal for maximizing growth in all conditions. The results suggest that maggot and taro leaf flour could be used as an alternative fish feed to reduce production costs in aquaculture. Further research is recommended to refine the feed formulation, particularly in pellet form, and to investigate the long-term effects of this feed on fish health and water quality in larger-scale production systems. Additionally, improvements in meeting the Indonesian National Standards (SNI) for tilapia farming, such as optimizing feeding frequency and dosage, are necessary to enhance the efficacy of this alternative feed strategy. Overall, while promising, this study highlights the need for continued development and evaluation to fully realize the benefits of maggot and taro leaf-based feeds in sustainable aquaculture practices.

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CONFLICT OF INTEREST

"The authors declare no conflict of interest."

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